

Scintillator Based Muon System R&D

http://www-d0.fnal.gov/~maciel/LCD/awg_lcdmu.html

Institutions/Collaborators

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Design Concepts

- μ ID from penetration of the Fe yoke instrumented with scintillator planes;
- Use the muon detector to measure shower leakage; CAL varies from $4 - 7\lambda$;
- Similar to a ν detector, but....

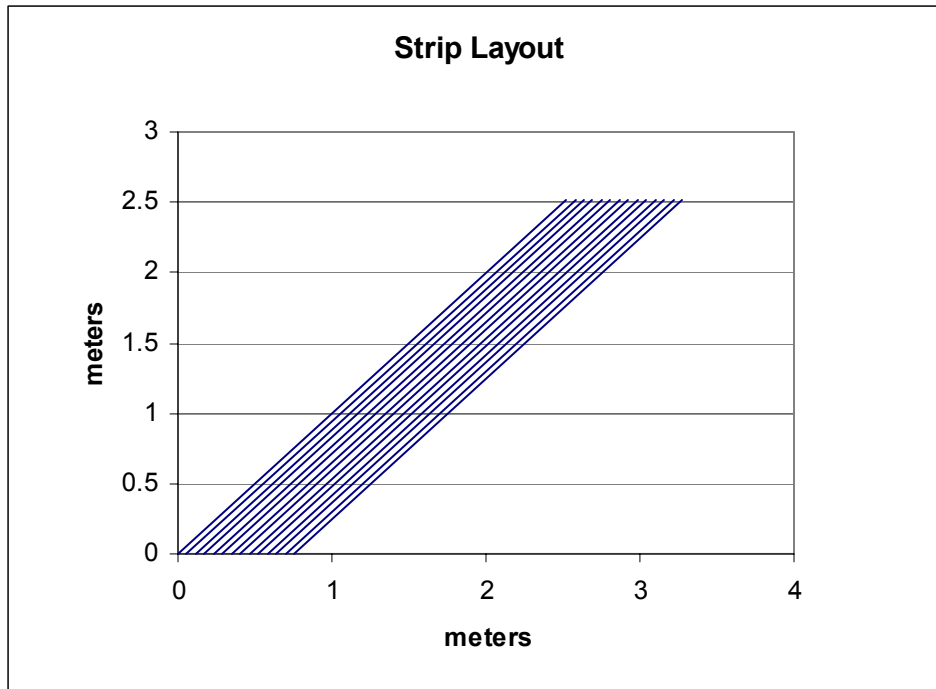
R & D is Needed - Why?

- How good is muon ID? For full LC menu?
- Does E-flow benefit from μ Cal?.
- Requires integration with barrel and forward tracking and calorimetry, structural Fe, solenoid, mechanical support, cables, etc.
- Robust design parameters - must be understood, optimized, cost estimated, reviewed....
- Best μ detector design?

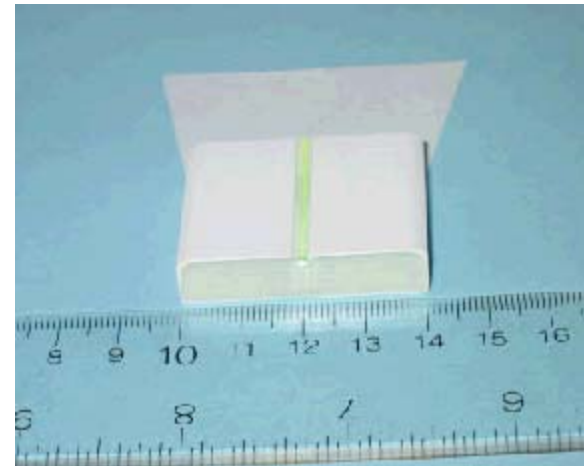
Mechanical Engineering

- Statics OK with 47T plates;
- Bolting appears to be possible structurally.
- Open questions:
 - Machined Fe?
 - Groove fitted?
 - Spokes a la CMS?
 - Bolted?
- Opportunities for further ME work here.

Scintillator Layout and Strips



U/V strips with wls shifted light exiting both ends. Add left/right signals from clear fibers to provide the pulse height sum.

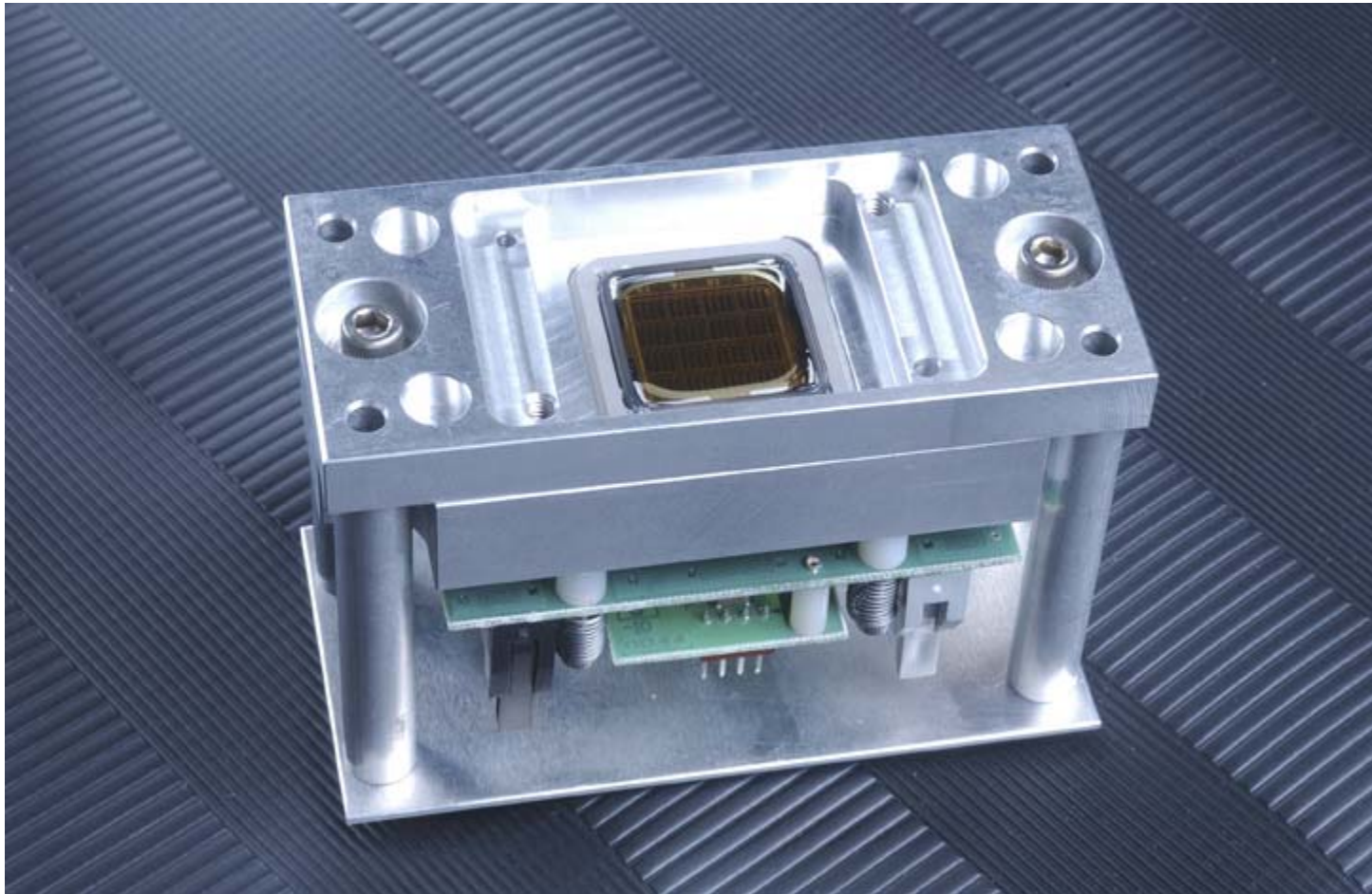


Scintillator: $4.1 \times 1 \text{ cm}^2$
co-extruded strips with
1 mm dia. WLS fiber and
outer reflector of TiO_2 .

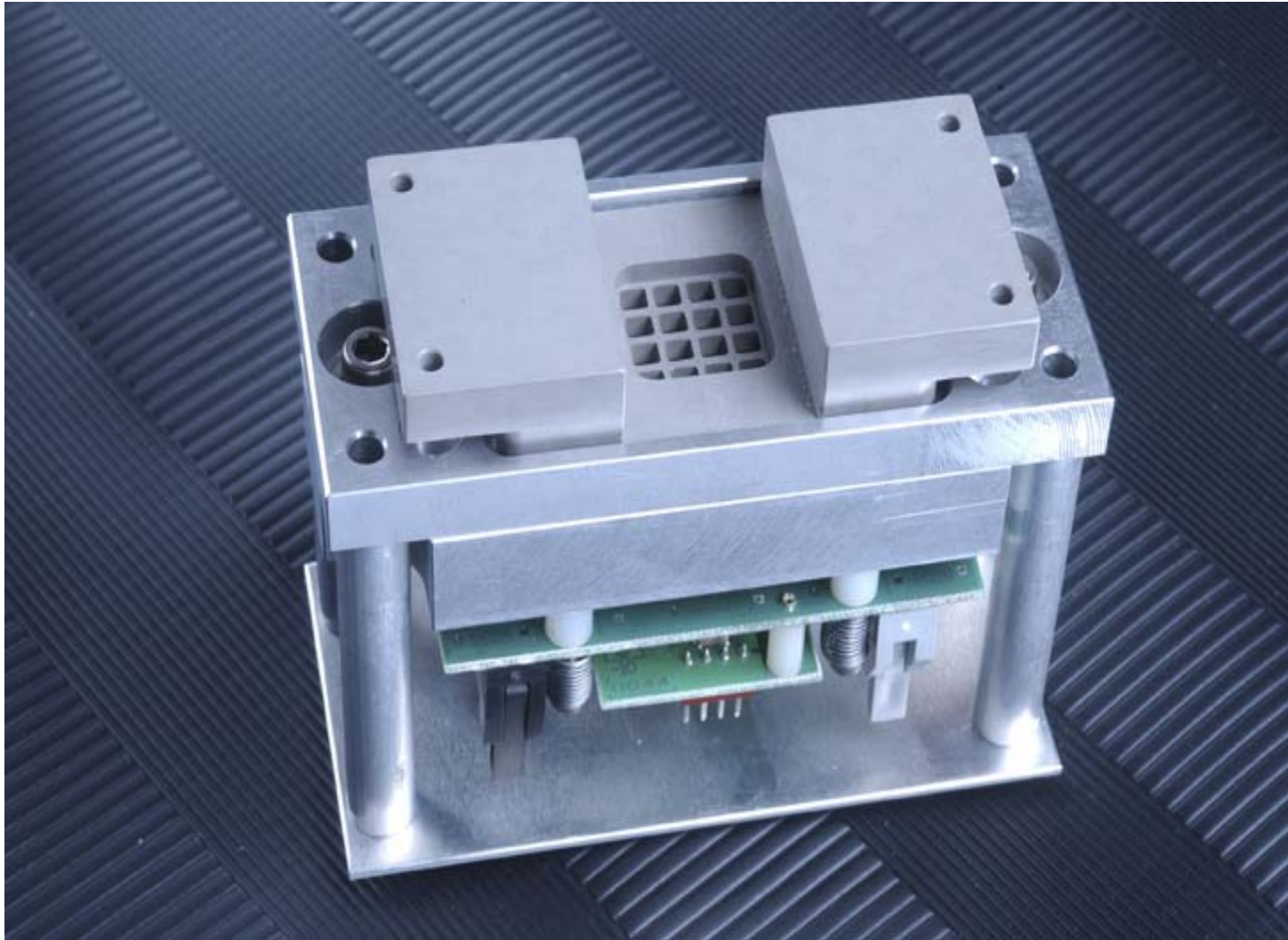
MINOS Hamamatsu H6568

Multi-anode PM

16 anodes ea. $4 \times 4 \text{ mm}^2$



MINOS - MAPMT with fiber guide



Scintillator and PMT Studies

- Hamamatsu H6568 MAPMTs loaned to us by MINOS. Wayne State => FE studies.
- Scintillator testing at Fermilab in Lab 5 & NIU in prep. for scint. extrusion mach.

NIU Test-stand for scintillator QC (Dychkant, Rykalin)

Fermilab Lab 5 tests using VLPCs (Bross + Coop. Std.):

1.2, 1.0, 0.5 mm fiber preliminary results.

- Setup of extrusion machine



Lab 5 at Fermilab

Berstorff Extrusion Machine
(purchased by NIU); being installed.
First articles of scintillator in June.

Extruded Scintillator R&D at Fermilab

- Studied Wavelength shifting (WLS) fiber readout of scintillator extrusions for possible future large scale detectors

- ♦ Scintillator: MINOS extrusions

- ▲ 1 X 4 cm - grooved

- ▲ TiO₂ reflector

- ♦ Scintillator: KEK prototype

- ▲ 1.2 X 2.5 cm - hole down the middle

- ▲ TiO₂ reflector

- ♦ WLS: Kuraray Y11

- ▲ 1.2 mm 175 ppm (MINOS Standard)

- ▲ 1.0 mm 200 ppm

- ▲ 0.5 mm 200 ppm

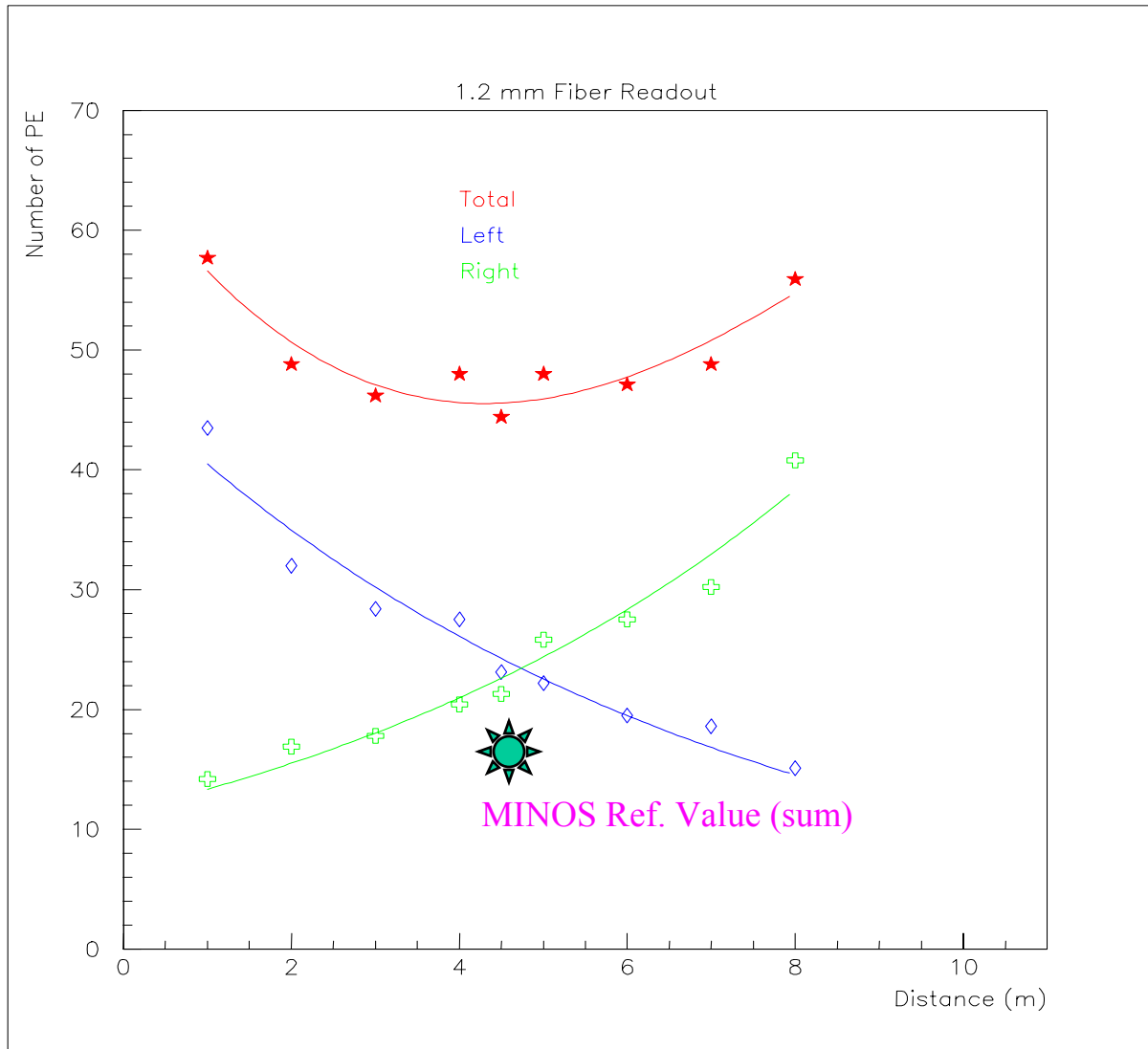
- ♦ Photodetector - Visible Light Photon Counter (VLPC)

- ▲ Used D0 HISTE VI devices

- QE=80-85%

- Gain \approx 60,000

VLPC Tests with MINOS Scintillator



• 1.2 mm WLS fiber (MINOS equivalent) results using VLPCs.

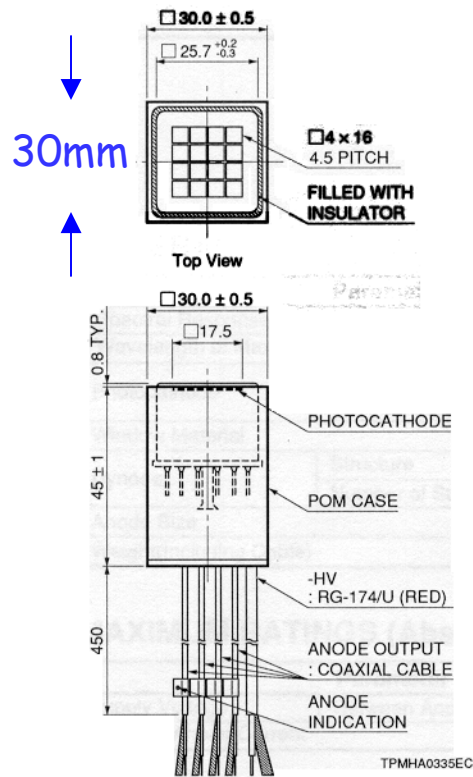
Tests of 1.0 & 0.5 mm fibers, etc.

Want to try co-extr of scint + fiber.

Alan Bross
March 2003

PM, Channel Count

16 channel
multi-anode PM



Hamamatsu H6568

	Barrel	Ends	Total
WLS Fibers	51,200	42,766	93,966
Clear Fibers			187,932
Scintillator			
Area (m ²)	7,174	4,353	9,527
Vol. (m ³)			95.3
M ($\rho=1.2\text{g/cm}^3$)			114.3T

Multiplexing fibers

How many fibers onto a single pixel?

MINOS (1.2mm fiber) \Rightarrow 8 fibers/pixel

\Rightarrow 128 fibers/MAPMT

188K fibers/128 fibers

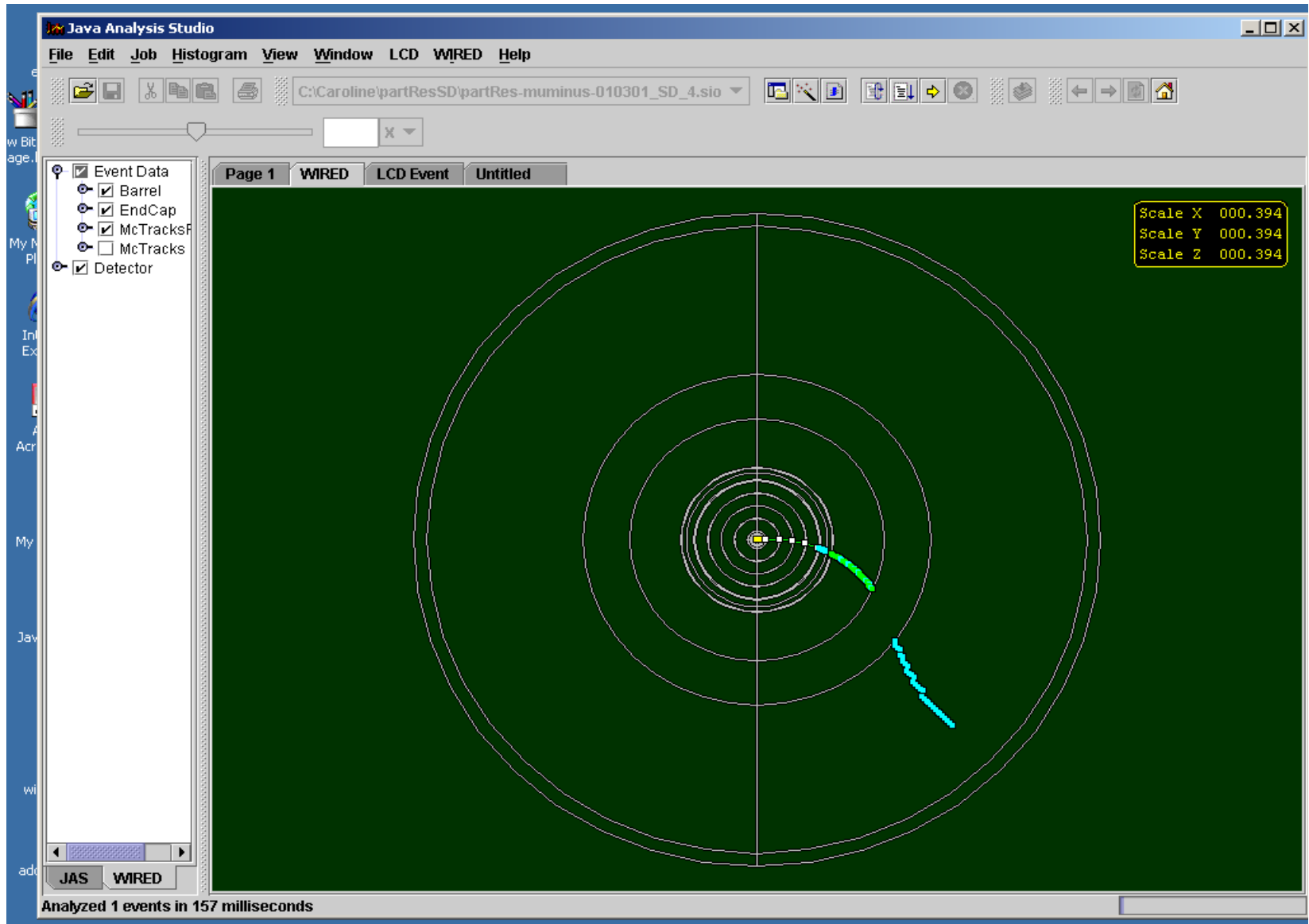
\Rightarrow 1500 MAPMTs

- Needs study and a calibration scheme

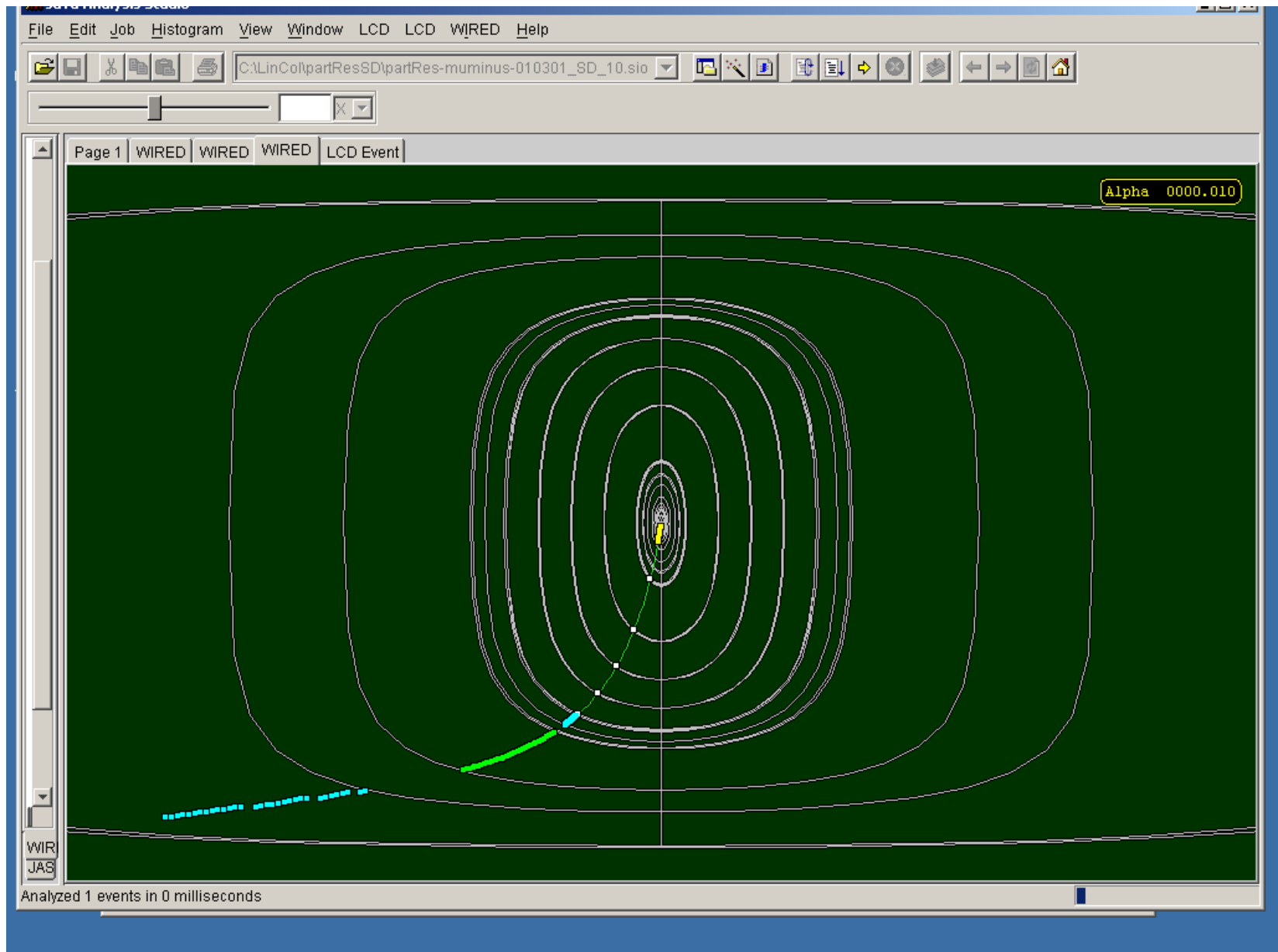
Simulation Software Development/Studies

- Development of LCD framework with GEANT4 simulation: Chakraborty, Maciel, Zutshi, *Lima*, students
 - Toward universal use;
 - Specific representations for Cal/Mu;
 - I/O compatibility with JAS & ROOT.
- Development of muon (calorimeter) analysis code: Maciel, Markelof, Milstene
 - Muon ID & tracking algorithms:
 - Studies of single muons and pions
 - Comparison with TESLA studies
 - Studies of various final states.
- We have looked only at SD muon geometry: detectors every 5 cm of Fe.

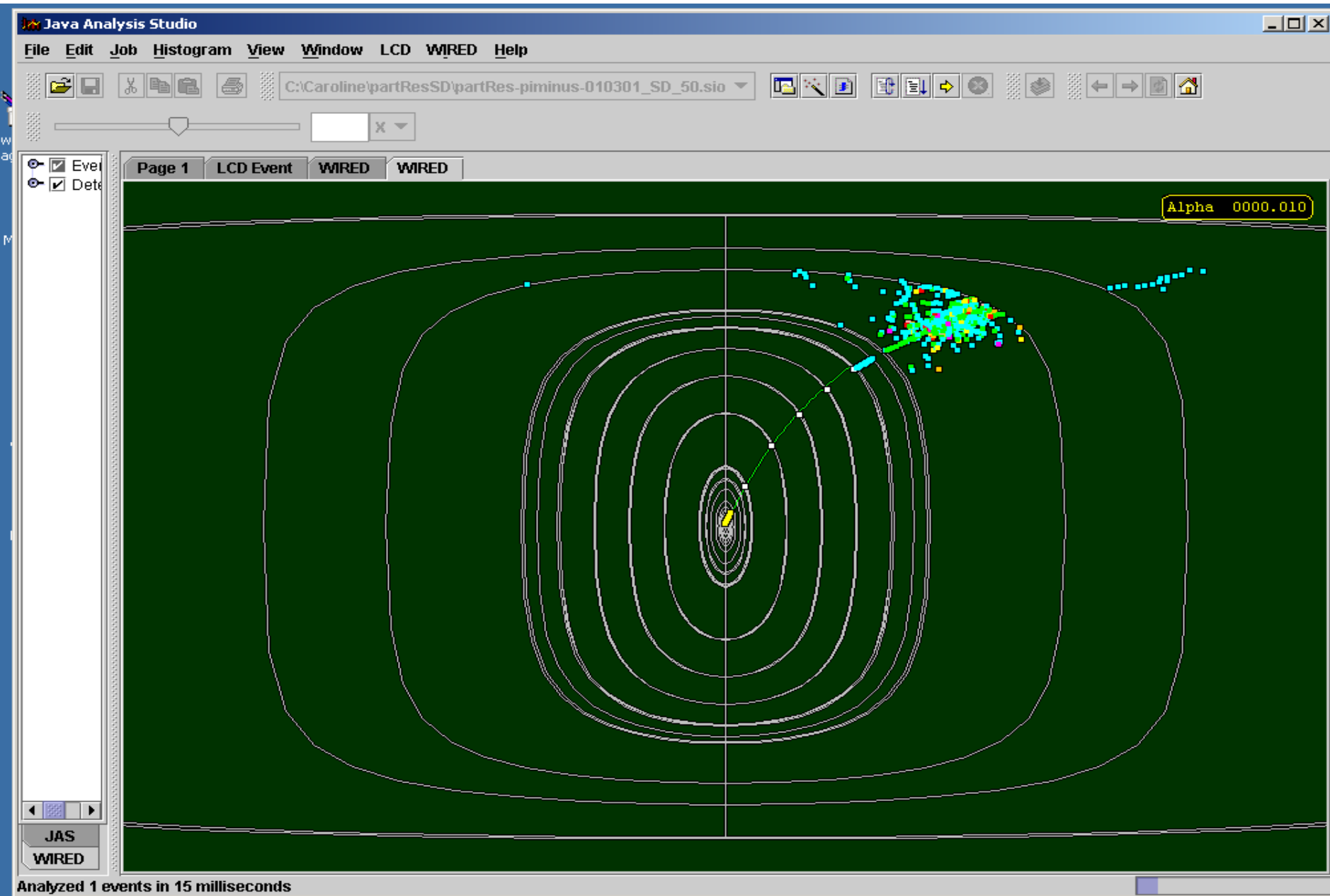
4 GeV μ^- Run 1 event 2 - 32 hits in the Muon Barrel



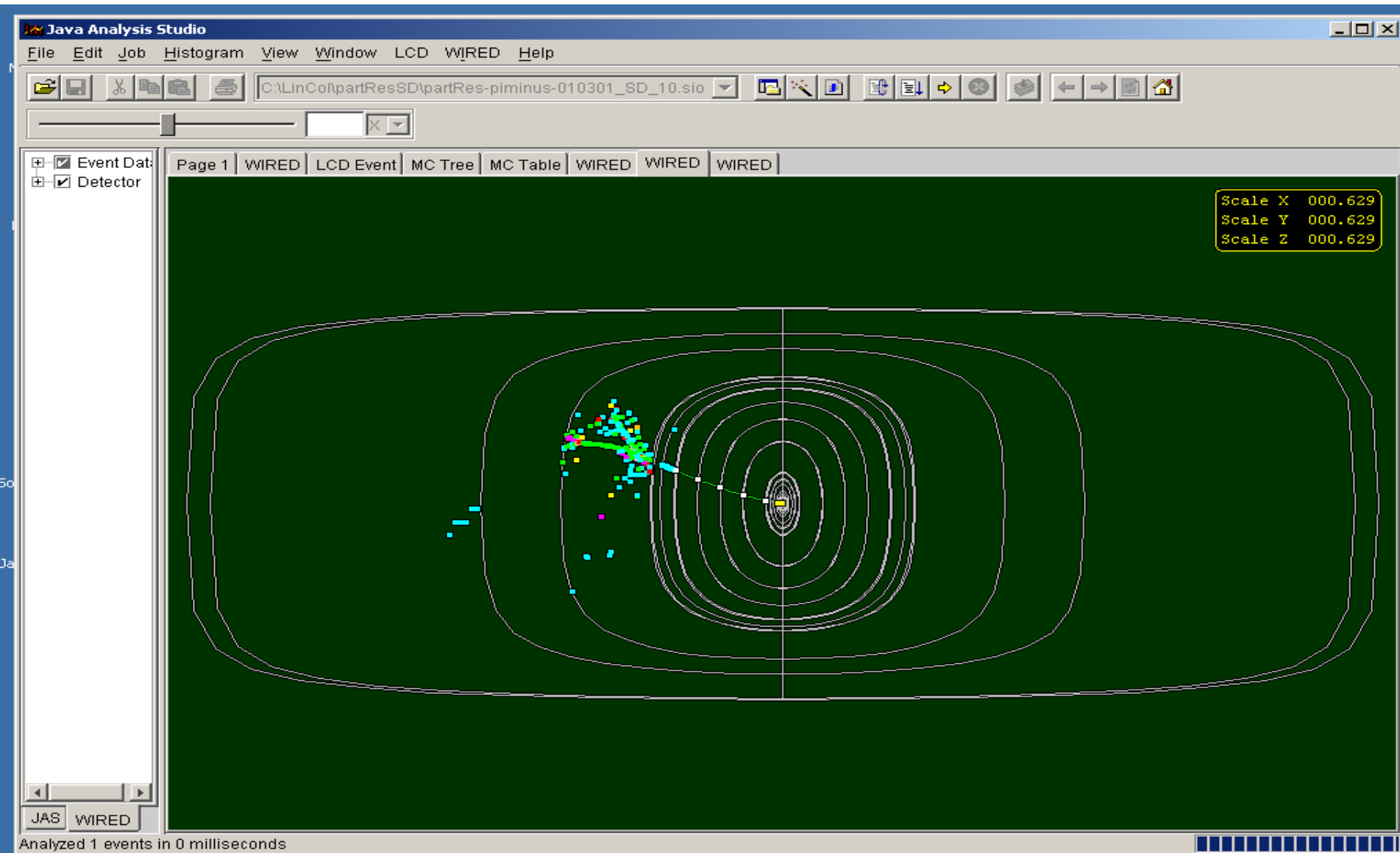
10 GeV μ^- Event 3 Run 1 with 33 Hits in MuDet



50 GeV π^- event 11 run 0 EyeFish View-18 hits in Muon Detector



10 GeV punchthrough π -event 118-Run1- 6 hits MuDet SD



Tracking Algorithm Development

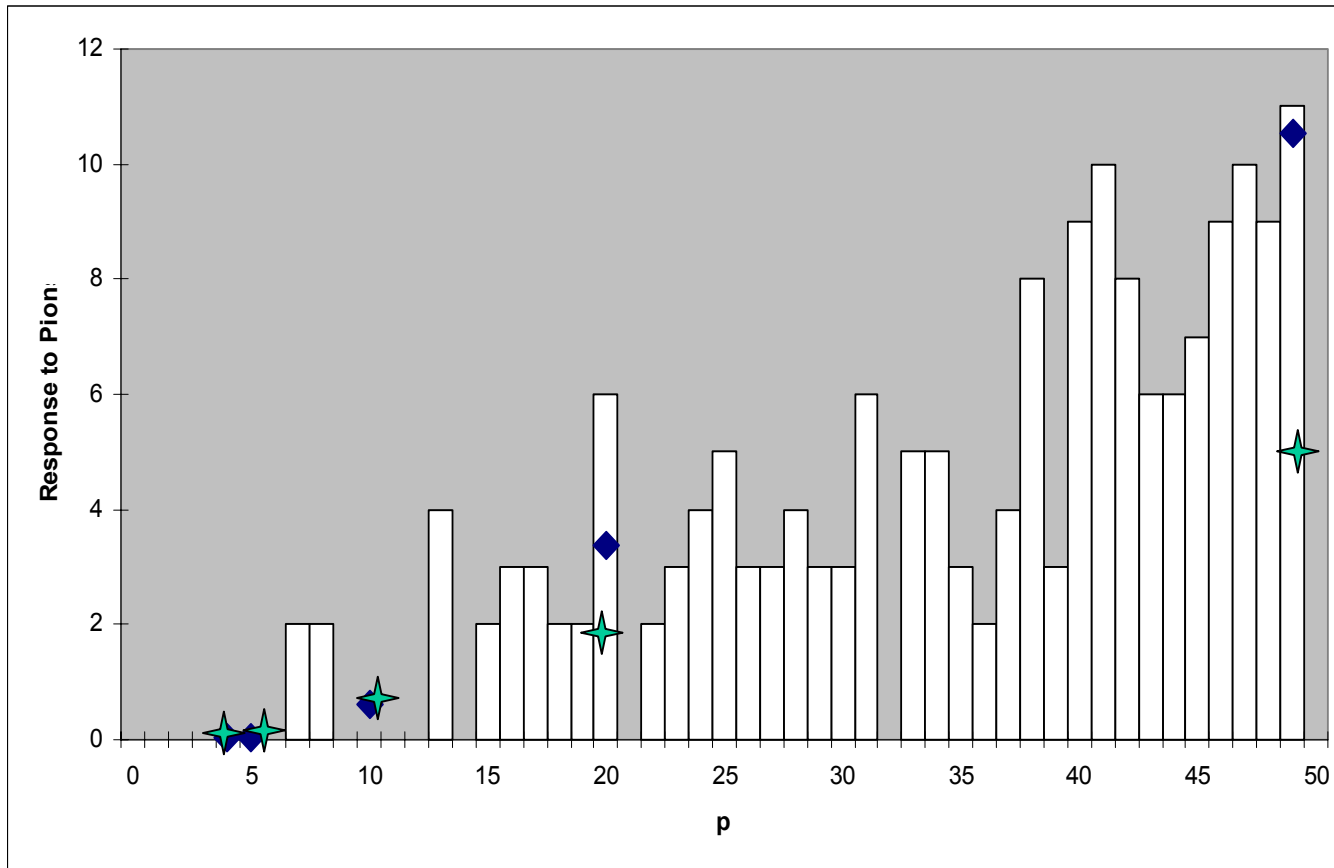
Use the basic algorithm developed by M. Piccolo : compare the muon candidate hits with the track extrapolated from central tracking. Use $\Delta\theta$ and $\Delta\phi$ cuts in doing the matching.

Study: Pion punchthrough vs momentum ($>80\text{cm } \mu \text{ Fe}$)
using a simple algorithm - 16 or more hits in 16 or more gaps in μ system (similar cut in Hcal) with
 $(\Delta\theta, \Delta\phi) < (3, 2)$ bins where ea. bin is 21 mr.

Remove π decays (less than 1% for $p_\mu > 3 \text{ GeV}$).

Find punch-through reaches about 1.5% at 50 GeV.
Smaller if one asks for 5 planes with g.e. 2 hits; hadron-like.

Pion Response of the Muon System



•The response to π reported for 35000 events (Tesla) By M . Piccolo has been Reproduced
The blue diamonds represent The SD Points for π after Normalization to account for the Difference in interaction length and statistics
The Green stars Correspond to an Extra cut: Requiring 5 planes with ≥ 2 hits

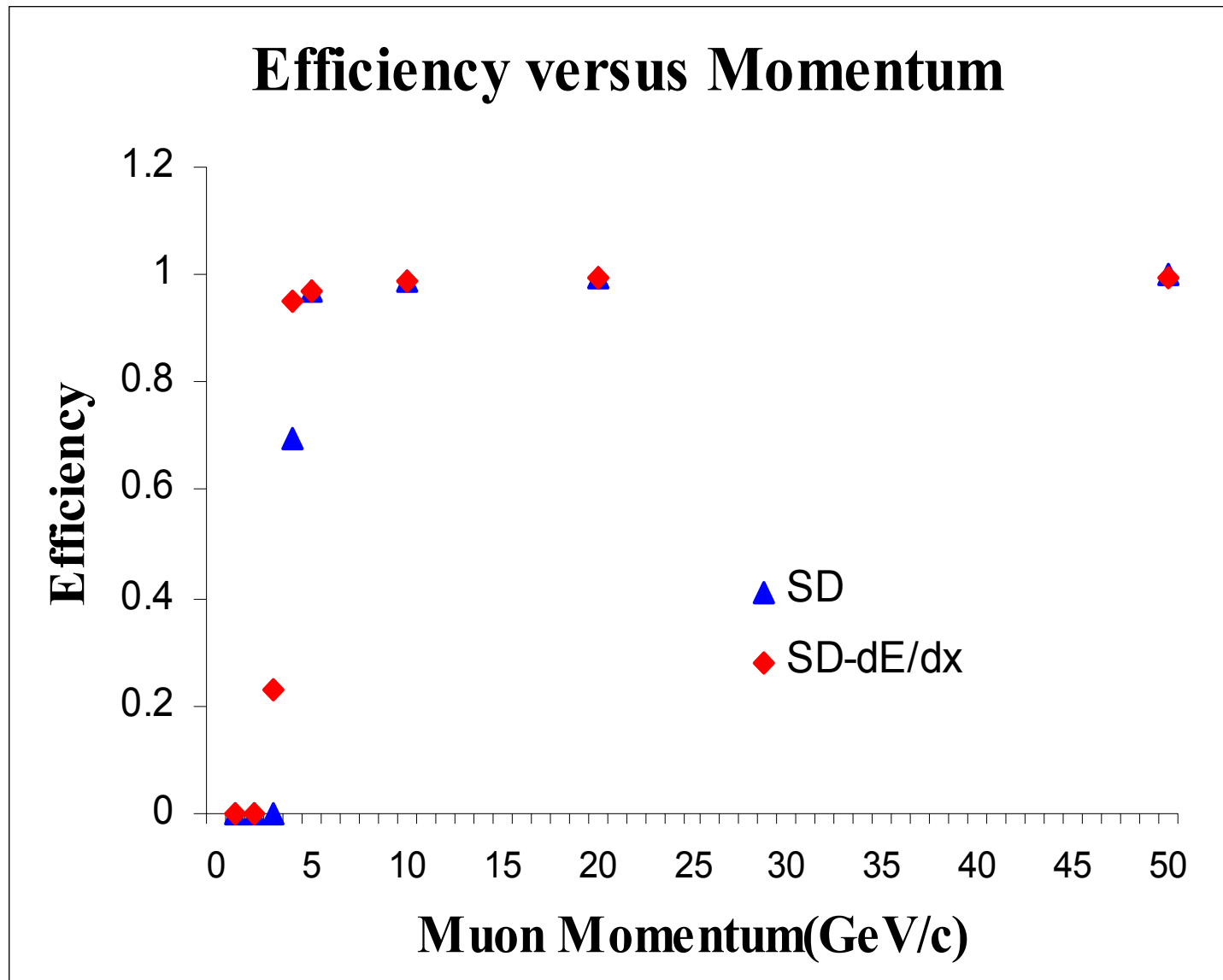
Improved low momentum muon ID

Inspection of the $(\Delta\theta, \Delta\phi)$ distributions as a function of p_μ showed asymmetric and skewed distributions. This was traced to a an omission of dE/dx in the projection of central tracks into the calorimeter and muon systems.

Fixing this problem has significantly improved the matching efficiency for low momentum muons, 3 to 6 GeV/c. e.g. the efficiency in the 3-4 GeV bin is 70%.

C. Milstene

Muon ID with dE/dx Correction

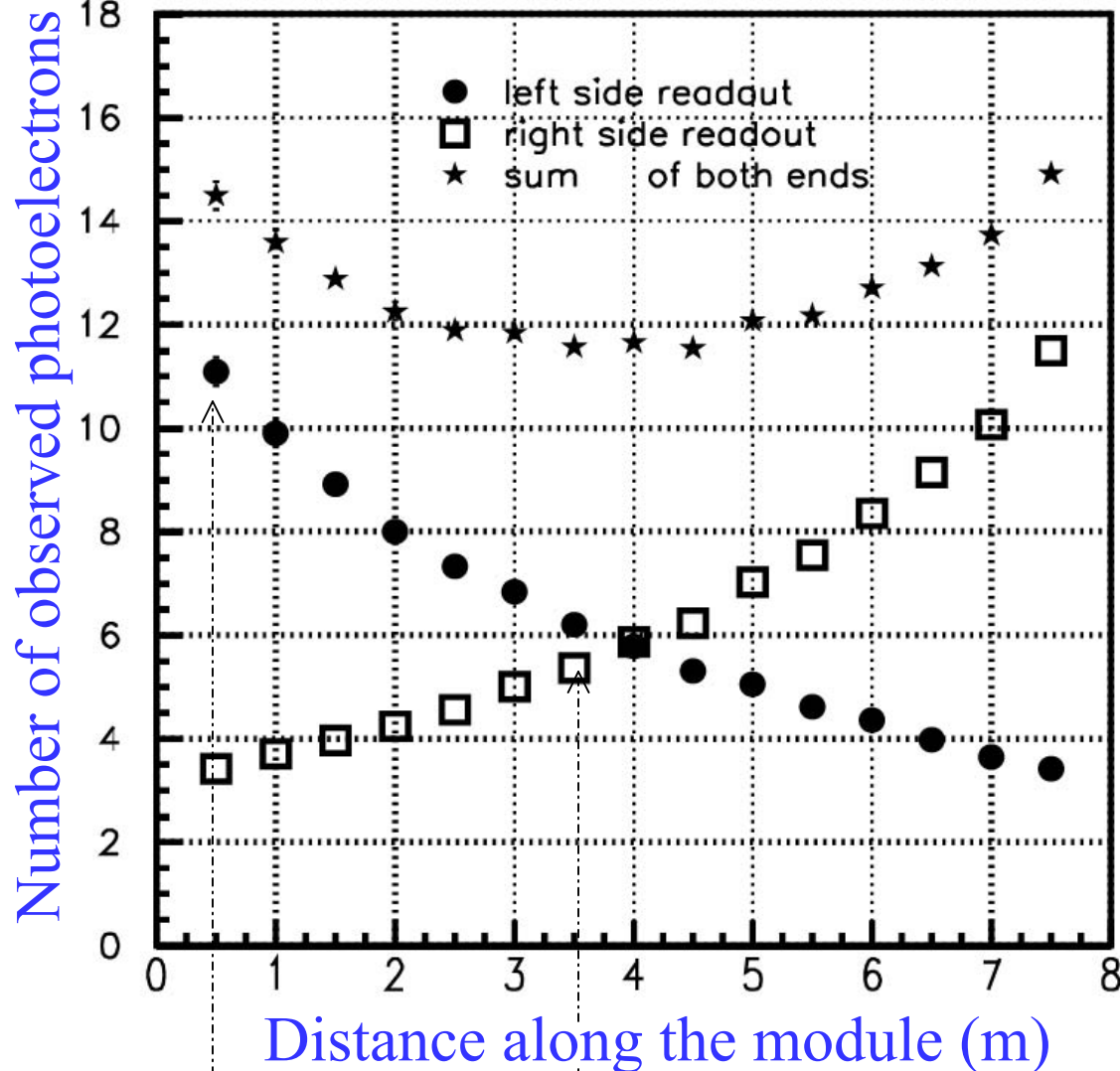


More to Do!

- Muon ID in jets may be possible. We need to look.
- Lack of progress on the muon system's use as a calorimeter - potentially important.
- Need advances in improved simulation software for planar detectors.
- Need to investigate utility of a set of (wire?) chambers between the solenoid and the muon Fe.
- How to handle and calibrate 188K channels?
- We lack personnel! More magnetism?

The ALC Muon Collaboration

- **Wayne State:** Paul Karchin - PMT studies, FE electronics specs, prototype electronics, physics studies. Needs funding for MAPMTs, (wo)manpower, travel.
- **UC Davis:** Mani Tripathi - Readout electronics, use existing RO to learn the important parameters. Needs input from Wayne State; needs money to involve others and travel to Fermilab.
- **NIU:** Arthur Maciel - Dhiman Chakraborty - the next generation of simulation software; generation/maintenance of SIO library files.
Sasha Dychkant/Vicor Rykalin scintillator development and testing. Can pay for student help with UCLC funding!
- **Notre Dame:** Mitch Wayne fiber expert; has manpower if he can pay for it - needs funding.
- **Fermilab:** There is a lot to do and we lack manpower!



MINOS Scintillator

Measured light output using the complete MINOS optical system: Connectors, clear fibers, multi-anode PMT's

Near
 11 ± 3 p.e.

Far (3.6 m for the proposed layout)
 6 ± 2 p.e.